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**Information in support of a Recovery  
Potential Assessment of Pugnose  
Shiner (*Notropis anogenus*) in Canada**

**L'information à l'appui de l'évaluation  
du potentiel de rétablissement du méné  
camus (*Notropis anogenus*) au Canada**

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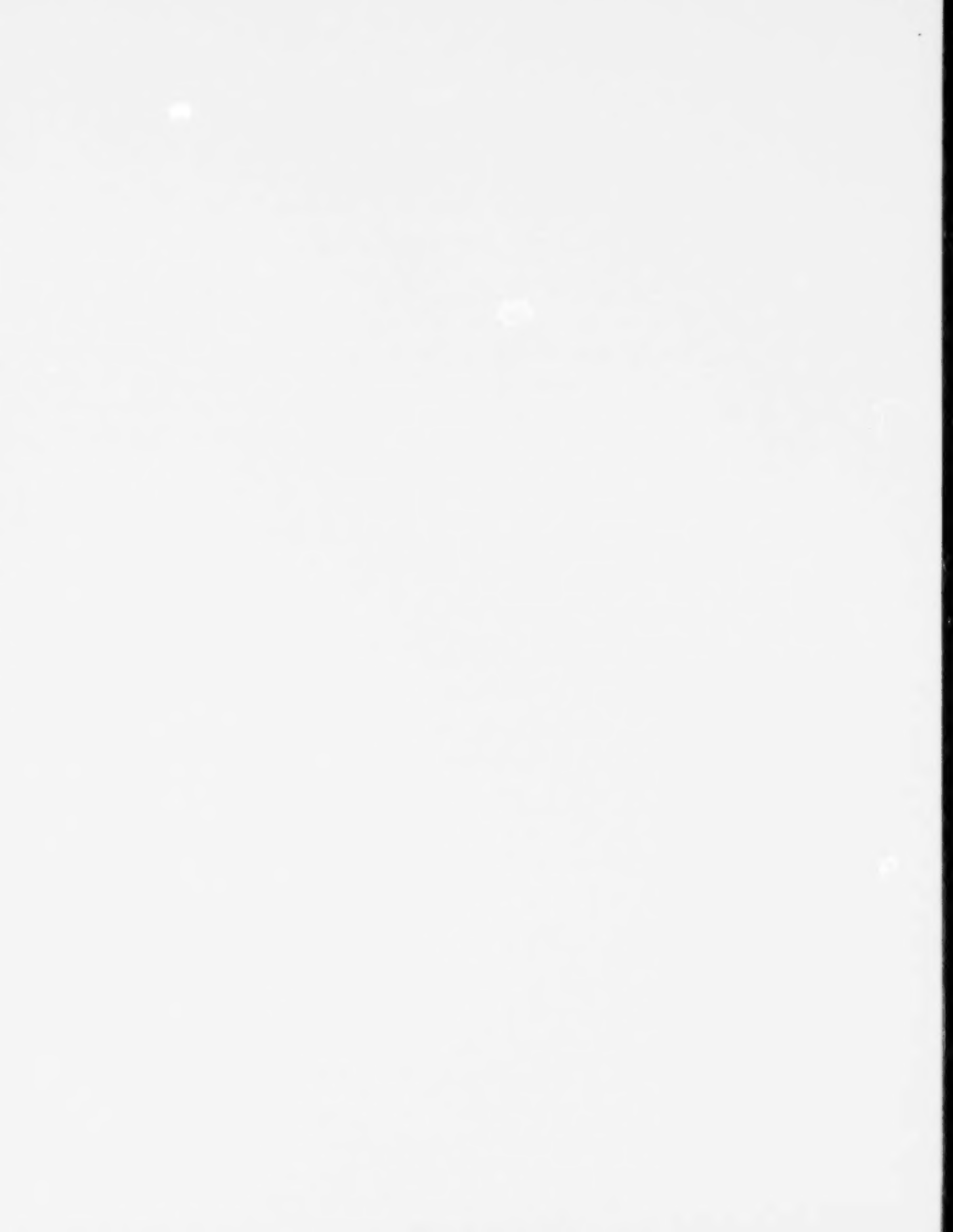
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## TABLE OF CONTENTS

ABSTRACT .....	v
RÉSUMÉ .....	v
SPECIES INFORMATION .....	1
BACKGROUND .....	1
CURRENT STATUS .....	2
POPULATION STATUS .....	6
HABITAT REQUIREMENTS .....	8
THREATS .....	9
THREAT STATUS .....	12
MITIGATIONS AND ALTERNATIVES .....	18
SOURCES OF UNCERTAINTY .....	19
REFERENCES .....	20
APPENDIX I. KEY TO PATHWAYS OF EFFECT .....	23



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**ABSTRACT**

In November 2002, the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) designated the Pugnose Shiner (*Notropis anogenus*) as Endangered. This designation was due to a limited, disjunct Canadian distribution. Pugnose Shiner was subsequently listed on Schedule 1 of the *Species at Risk Act* (SARA) when the act was proclaimed in June 2003. The Recovery Potential Assessment (RPA) provides information and scientific advice needed to fulfill various requirements of SARA including permitting activities that would otherwise violate SARA prohibitions and the development of recovery strategies. This Research Document describes the current state of knowledge of the biology, ecology, distribution, population trends, habitat requirements, and threats of Pugnose Shiner. Mitigation measures and alternative activities related to the identified threats, that can be used to protect the species, are also presented. The information contained in the RPA and this document may be used to inform the development of recovery documents and for assessing SARA Section 73 permits.

**RÉSUMÉ**

En novembre 2002, le Comité sur la situation des espèces en péril au Canada (COSEPAC) a désigné le méné camus (*Notropis anogenus*) en tant qu'espèce « en voie de disparition ». Cette désignation est justifiée par le fait que l'espèce a une aire de répartition limitée et disjuncte au Canada. Le méné camus a ensuite été inscrit à l'annexe 1 de la *Loi sur les espèces en péril* (LEP) lorsque l'acte a été proclamée en juin 2003. L'évaluation du potentiel de rétablissement (EPR) fournit l'information et l'avis scientifique dont on a besoin pour respecter les diverses exigences de la LEP, y compris la délivrance de permis pour mener des activités qui, d'une autre façon, contreviendraient à la LEP, ainsi que pour élaborer des programmes de rétablissement. Le présent document de recherche décrit l'état actuel des connaissances sur la biologie, l'écologie, l'aire de répartition, les tendances démographiques et les besoins en matière d'habitat du méné camus ainsi que sur les menaces pesant sur cette espèce. Des mesures d'atténuation et des solutions de rechange pour les activités constituant une menace qui pourraient être mises en œuvre pour protéger l'espèce sont également présentées. L'information contenue dans l'EPR et dans le présent document pourrait être utilisée à l'appui de l'élaboration de documents concernant le rétablissement et de l'évaluation des permis délivrés en vertu de l'article 73 de la LEP.



## SPECIES INFORMATION

**Scientific Name** – *Notropis anogenus*

**Common Name** – Pugnose Shiner

**Current COSEWIC Status & Year of Designation** – Endangered, 2002

**COSEWIC Reason for Designation**<sup>1</sup> – The Pugnose Shiner has a limited, fragmented Canadian distribution, being found only in Ontario where it is subject to declining habitat quality. The isolated nature of its preferred habitat may prevent connectivity of fragmented populations and may prevent gene flow between existing populations and inhibit re-colonization of other suitable habitats.

**SARA Schedule** – 1

**Range in Canada** – Ontario

## BACKGROUND

The Pugnose Shiner (*Notropis anogenus* Forbes, 1885) is a small fish with a slender, elongate body (Scott and Crossman 1973). The largest recorded Canadian specimen is 72 mm (total length; ROM 79046), while average total length is 38-51 mm (Scott and Crossman 1973; Becker 1983). The overall colouration is silver, and it generally has pale yellow to olive tints on the back (Holm and Mandrak 2002). It has a prominent dark lateral band that extends from a wedge-shaped blotch at the base of the caudal fin forward onto the snout including the chin, lower lip, and side of upper lip, and scales on the back are darkly outlined (Scott and Crossman 1973; Becker 1983). The Pugnose Shiner has an extremely small, upturned mouth, which is positioned almost vertical to the body axis (Becker 1983; Holm and Mandrak 2002). The Pugnose Shiner is generally found in highly vegetated, clear, slow-moving water, which acts as an optimal site for breeding and feeding (Holm and Mandrak 2002). It is believed that the loss of this optimal habitat is a leading cause in the decline of the Pugnose Shiner.

There is an overlap in Pugnose Shiner distribution with various similar blackline shiners that may lead to confusion when identifying this species including Blackchin Shiner (*Notropis heterodon*), Blacknose Shiner (*Notropis heterolepis*), and Bridle Shiner (*Notropis bifrenatus*). A few key characteristics exist to distinguish Pugnose Shiner from these species. Most notably, other blackline shiners have larger, less upturned mouths (Holm *et al.* 2009). In addition, Blacknose and Bridle shiners do not have any colouration on their chin. The Pugnose Shiner is also often confused with the Pugnose Minnow (*Opsopoeodus emiliae*), although these two species are distinguishable by the number of dorsal fin rays; the Pugnose Shiner generally has eight rays, while the Pugnose Minnow has nine (Holm *et al.* 2009).

Habitat loss and degradation is considered the primary threat in the decline of Pugnose Shiner populations in Canada (Holm and Mandrak 2002). Factors associated with the decline in habitat quality include an increase in agricultural and land use practices resulting in increased sediment and nutrient loading. Declines in habitat quantity can be attributed to the habitat modifications, or the removal of aquatic vegetation. Another threat hypothesized to limit the occurrence of this species includes shifts in trophic dynamics from a cyprinid-based to a centrarchid-based community. This shift has been marked by a noticeable decline in cyprinid abundance in certain areas. The introduction of invasive species, such as Common Carp (*Cyprinus carpio*) and Eurasian watermilfoil (*Myriophyllum spicatum*), is also thought to negatively affect Pugnose Shiner populations (Lyons 1989). Climate change and incidental harvest through the baitfish

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<sup>1</sup> <http://www.cosewic.gc.ca/eng>

industry may also play a role in the decline of Pugnose Shiner, although the degree to which these threats are affecting Pugnose Shiner is still unknown.

A meeting of the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) in November 2002 recommended that the Pugnose Shiner be designated as Endangered, due to its limited, disjunct Canadian distribution (COSEWIC 2009). Subsequent to the COSEWIC designation, Pugnose Shiner was included on Schedule 1 of the *Species at Risk Act* (SARA) when the act was proclaimed in June 2003. A Recovery Potential Assessment (RPA) process has been developed by Fisheries and Oceans Canada (DFO) to provide information and scientific advice needed to fulfill SARA requirements, including the development of recovery strategies and authorizations to carry out activities that would otherwise violate SARA (DFO 2007). This document provides background information on the Pugnose Shiner to inform the RPA.

## **CURRENT STATUS**

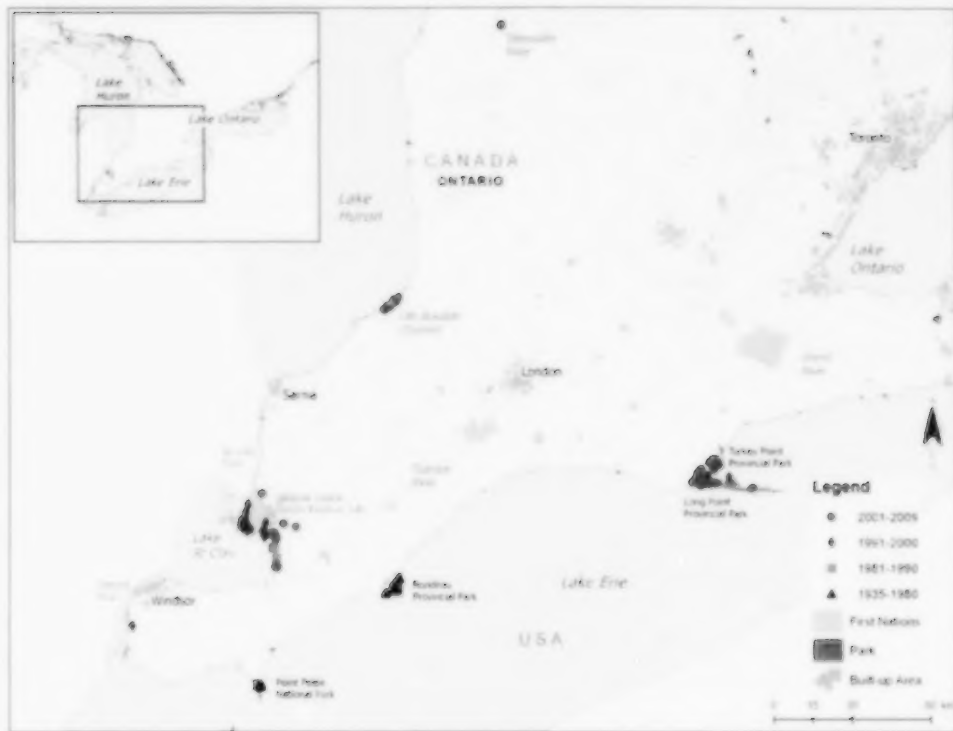
The current and historical distribution of the Pugnose Shiner is limited to four distinct areas of the Great Lakes basin; Lake Erie drainage; southern Lake Huron drainage; eastern Lake Ontario drainage; and, Lake St. Clair drainage (Figure 1A, 1B). Historical records have been noted for the Lake Erie drainage (Long Point Bay including the Long Point National Wildlife Area (NWA), Point Pelee National Park, and Rondeau Bay), and eastern Lake Ontario drainage, with records from the St. Lawrence and Gananoque rivers.

Recent sampling of the Lake Erie drainage has verified the presence of Pugnose Shiner at Long Point Bay (including NWA), but have failed to detect the presence of Pugnose Shiner in both Point Pelee National Park and Rondeau Bay. An additional record from the Lake Erie drainage was noted from the mouth of the Canard River. Recent sampling has detected the presence of the Pugnose Shiner in the Lake Huron drainage from both the Old Ausable Channel and the Teeswater River (a tributary of the Saugeen River). Sampling has confirmed the persistence of Pugnose Shiner in the eastern Lake Ontario drainage at the St. Lawrence River, and detected the occurrence of Pugnose Shiner at West Lake (Prince Edward County). In addition, Pugnose Shiner have been detected in the Lake St. Clair drainage at Walpole Island, Mitchell's Bay, St. Clair National Wildlife Area, and three Lake St. Clair tributaries (Whitebread Drain/Grape Run, Little Bear Creek and MacLeod Creek).

## **LAKE ERIE DRAINAGE**

### **Long Point Bay**

Long Point Bay represents one of the few historical locations where Pugnose Shiner is still extant. For the purposes of this report, Long Point Bay will encompass the entire Inner Long Point Bay, including Long Point National Wildlife Area – Thoroughfare Point Unit, and the area east of Turkey Point. Historically, Pugnose Shiner was caught in Long Point Bay in 1947 and 1996 (Holm and Mandrak 2002). In a 2004 fish community survey conducted by DFO, Pugnose Shiner was detected in Long Point Bay ( $n=29$ ), and in the Thoroughfare Point Unit of Long Point National Wildlife Area ( $n=1$ ; Marson *et al.* 2007). Additionally, a 2007 survey conducted at eight sites at Turkey Point resulted in the capture of 38 Pugnose Shiner (S. Staton, DFO, pers. comm.).



**Figure 1A.** Distribution of Pugnose Shiner in southwestern Ontario.

Sampling completed by DFO in 2008 and 2009 yielded an additional 22 individuals (DFO, unpubl. data).

#### **Point Pelee National Park**

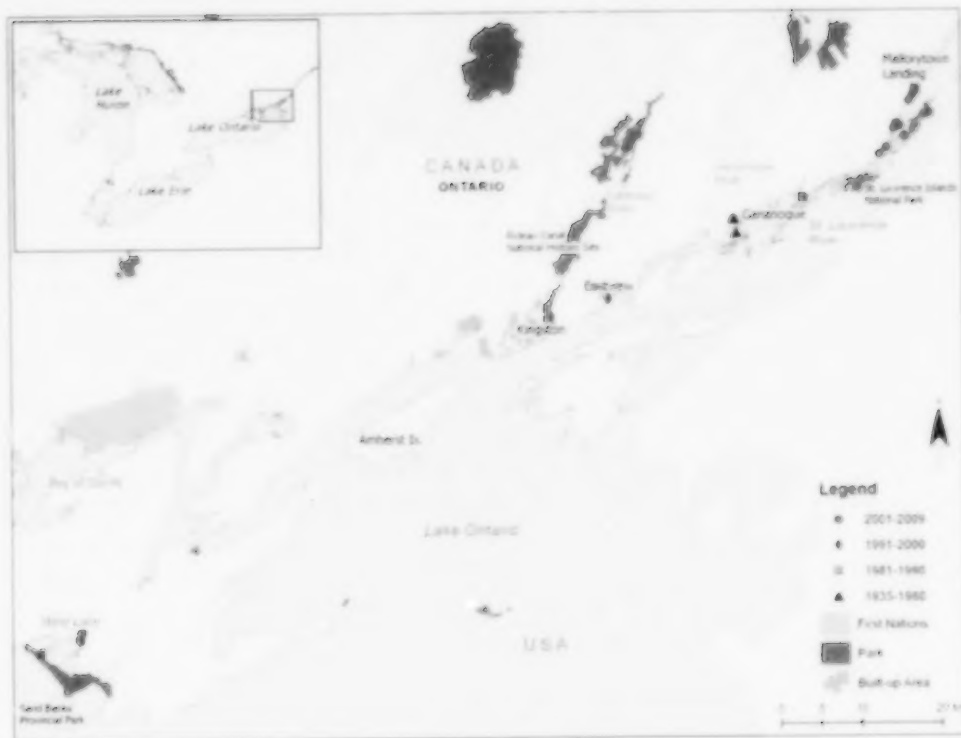
Historical records for Pugnose Shiner were recorded from Point Pelee National Park in 1940 and 1941 (Holm and Mandrak 2002). Surveys at this site dating back to 1946, with more recent surveys between 1979 and 2004 have not detected any Pugnose Shiner. It is believed that Pugnose Shiner is likely extirpated from Point Pelee National Park.

#### **Rondeau Bay**

Historical records for Pugnose Shiner in Rondeau Bay date back to 1940 and 1963 (Holm and Mandrak 2002). Recent surveys of this area have failed to detect any additional Pugnose Shiner, and it is believed that the Rondeau Bay population may be extirpated.

#### **Canard River**

A total of four Pugnose Shiner vouchers were collected from the wetlands located at the mouth of the Canard River in 1994 (Royal Ontario Museum, unpubl. data). Subsequent sampling in this area has not resulted in the capture of any additional Pugnose Shiner.



**Figure 1B.** Distribution of Pugnose Shiner in eastern Ontario.

## LAKE HURON DRAINAGE

### Old Ausable Channel

Pugnose Shiner was first detected in the Old Ausable Channel (Ausable River watershed) in the early 1980s, and subsequently captured in 1997, 2002, 2004, 2005 and 2009 (ARRT 2005; ABCA, unpubl. data; DFO, unpubl. data). Although sampling in the Old Ausable Channel has been sporadic, it is believed that the Pugnose Shiner population may be stable.

### Teeswater River

A total of four Pugnose Shiner have been caught from the Teeswater River (Saugeen River tributary). Three vouchers were captured in 2005, while the fourth was captured in 2009. The first two were captured from below a dam within the main branch of the river, the third from the tailrace, and the fourth from Cargill Mill Pond, a reservoir of the Teeswater River (S. D'Amelio, Trout Unlimited, pers. comm.; Marson *et al.* draft; DFO, unpubl. data).

## LAKE ST. CLAIR DRAINAGE

### Lake St. Clair

In Lake St. Clair, Pugnose Shiner are known to occur in Mitchell's Bay, St. Luke's Bay, and the coastal marshes surrounding Walpole Island (Holm and Mandrak 2002). Pugnose Shiner were captured in Mitchell's Bay in 1983, 1996, 1999 and 2006 (DFO, unpubl. data), and in St. Luke's Bay in 1983 and 2006 (Holm and Mandrak 2002; DFO, unpubl. data). A targeted, wadeable

survey conducted by DFO in the Lake St. Clair watershed in 2003 detected the presence of Pugnose Shiner in Little Bear Creek and Whitebread Drain/Grape Run, two tributaries of Lake St. Clair. Subsequent sampling conducted in 2006, detected nine additional individuals in MacLeod Creek (ROM, unpubl. data). A total of 31 additional sites in Lake St. Clair were sampling in 2007; however, no Pugnose Shiner were detected (DFO, unpubl. data).

In 1999, 281 Pugnose Shiner were detected in the coastal marshes of Walpole Island (Holm and Mandrak 2002), and this species was detected in this area once again in 2002 (ROM, unpubl. data). Within the Walpole Island complex, there are three partially diked areas: Pottowatamie Island; Walpole Island; and, St. Anne Island. Since these cells are often breached and there is a continuous exchange of water between the cells and Lake St. Clair proper through the use of pumps, the Pugnose Shiner captured in the cells may have originated from Lake St. Clair. For the remainder of this report, all Pugnose Shiner captured in Mitchell's Bay, St. Luke's Bay, the coastal marshes surrounding Walpole Island and all associated tributaries of Lake St. Clair will be referred to as the Lake St. Clair population.

#### **St. Clair National Wildlife Area (NWA)**

Pugnose Shiner was detected for the first time in the St. Clair National Wildlife Area (NWA) in 2003, and once more in 2004, during a graduate student project on wetland fish community structure; each detection consisted of a single record (DFO, unpubl. data).

### **LAKE ONTARIO DRAINAGE**

#### **Gananoque River/St. Lawrence River**

Pugnose Shiner was originally collected in 1935 from the Gananoque River, and the mouth of the Gananoque River in the St. Lawrence River (Toner 1937; cited in Holm and Mandrak 2002). Since this original record, Pugnose Shiner have not been collected in the Gananoque River, and were last recorded at the mouth of the Gananoque River in the St. Lawrence River in 1937. However, Pugnose Shiner have been captured both east and west of this original location at Mallorytown Landing and Eastview, respectively (Holm and Mandrak 2002). Sampling completed in 2005 by DFO at three sites in the St. Lawrence Islands National Park yielded 256 individuals (Mandrak *et al.* 2006).

Sampling completed throughout the Thousand Islands area by Parks Canada Agency detected 18 additional sites from east of Mallorytown Landing to west of Gananoque in the Bateau Channel inhabited by Pugnose Shiner (J. Van Wieren, Parks Canada Agency, pers. comm.). DFO targeted sampling from 2009 yielded the capture of 344 individuals (DFO, unpubl. data).

#### **West Lake**

Two Pugnose Shiner were collected from West Lake (Prince Edward County, eastern Lake Ontario) during a fish assemblage electrofishing study conducted by DFO in June 2009 (DFO, unpubl. data). This was the first time Pugnose Shiner had been collected in this area. In September 2009, additional sampling was completed in this area targeting Pugnose Shiner preferred habitat and an additional 32 vouchers were collected (DFO, unpubl. data).

## POPULATION STATUS

No studies have been completed specifically on the abundance of Pugnose Shiner throughout its Canadian distribution; therefore, it is not possible to discuss quantitative population estimates. However, repetitive sampling at select Pugnose Shiner sites does allow a comparison of population trends (Holm and Mandrak 2002). Historical records of Pugnose Shiner are available for three locations in the Lake Erie drainage (Long Point Bay, Point Pelee, Rondeau Bay), and one location in eastern Lake Ontario (Gananoque River). More recent surveys at all of the historic sampling locations have only detected Pugnose Shiner at Long Point Bay, indicating that it is probable that the only extant historical Pugnose Shiner population is present at Long Point Bay (Holm and Mandrak 2002). Despite the loss of these historical populations, new Pugnose Shiner populations have been detected in Lake St. Clair, St. Clair National Wildlife Area, Old Ausable Channel, Teeswater River, Canard River, and St. Lawrence River (east of the historical location and West Lake).

To assess the population status of Pugnose Shiner populations in Canada, each population was ranked in terms of its abundance (Relative Abundance Index) and trajectory (Population Trajectory) (Table 1).

**Table 1.** Relative Abundance Index and Population Trajectory of each Pugnose Shiner population in Ontario. Certainty has been associated with the Relative Abundance Index, and Population Trajectory rankings and is listed as: 1=quantitative analysis; 2=CPUE or standardized sampling; 3=best guess.

Population	Relative Abundance Index	Certainty	Population Trajectory	Certainty
<b>Lake Erie drainage</b>				
Long Point Bay	Low	2	Unknown	2
Canard River	Unknown	3	Unknown	3
Point Pelee	Extirpated	3	Not applicable	3
Rondeau Bay	Extirpated	3	Not applicable	3
<b>Lake Huron drainage</b>				
Old Ausable Channel	Medium	2	Stable	2
Teeswater River	Unknown	3	Unknown	3
<b>Lake St. Clair drainage</b>				
Lake St. Clair	Medium	2	Stable	2
St. Clair NWA	Unknown	3	Unknown	3
<b>Lake Ontario drainage</b>				
St. Lawrence River	High	2	Stable	2
Gananoque River	Extirpated	3	Not applicable	3
West Lake	Unknown	2	Unknown	2

The Relative Abundance Index was assigned as Extirpated, Low, Medium, High or Unknown. Sampling parameters, such as gear used, area sampled, sampling effort, and whether the study was targeting Pugnose Shiner, were considered. The number of individual Pugnose Shiner caught during each sampling period was then considered when assigning the Relative Abundance Index. The Relative Abundance Index is a relative parameter in that the values assigned to each population are relative to what is considered to be the most abundant population. In the case of Pugnose Shiner, all populations were assigned an Abundance Index relative to the St. Lawrence population (Lake Ontario drainage).

The Population Trajectory was assessed as Decreasing, Stable, Increasing, or Unknown for each population based on the best available information about the current trajectory of the population. The number of individuals caught over time for each population was considered. Trends over time were classified as Increasing (an increase in abundance over time), Decreasing (a decrease in abundance over time) and Stable (no change in abundance over time). If insufficient information was available to identify the trajectory, the Population Trajectory was listed as Unknown.

The Relative Abundance Index and Population Trajectory values were then combined in the Population Status matrix (Table 2) to determine the Population Status for each population. Each Population Status was subsequently ranked as Poor, Fair, Good, Unknown or Extirpated (Table 3).

**Table 2.** The Population Status Matrix combines the Relative Abundance Index and Population Trajectory rankings to establish the Population Status for each Pugnose Shiner population in Canada. The resulting Population Status has been categorized as Extirpated, Poor, Fair, Good, or Unknown.

		Population Trajectory			
		Increasing	Stable	Decreasing	Unknown
Relative Abundance Index	Low	Poor	Poor	Poor	Poor
	Medium	Fair	Fair	Poor	Poor
	High	Good	Good	Fair	Fair
	Unknown	Unknown	Unknown	Unknown	Unknown
	Extirpated	Extirpated	Extirpated	Extirpated	Extirpated

**Table 3.** Population Status for all Pugnose Shiner populations in Canada, resulting from an analysis of both the Relative Abundance Index and Population Trajectory. Certainty assigned to each Population Status is reflective of the lowest level of certainty associated with either initial parameter (Relative Abundance Index, or Population Trajectory).

Population	Population Status	Certainty
<b>Lake Erie drainage</b>		
Long Point Bay	Poor	2
Canard River/Detroit River	Unknown	3
Point Pelee	Extirpated	3
Rondeau Bay	Extirpated	3
<b>Lake Huron drainage</b>		
Old Ausable Channel	Fair	2
Teeswater River	Unknown	3
<b>Lake St. Clair drainage</b>		
Lake St. Clair	Fair	2
St. Clair National Wildlife Area	Unknown	3
<b>Lake Ontario drainage</b>		
St. Lawrence River	Good	2
Gananoque River	Extirpated	3
West Lake	Unknown	2

## HABITAT REQUIREMENTS

### SPAWNING

Pugnose Shiner are known to spawn in densely-vegetated, shallow water (2 m maximum depth), where the substrate is composed of sand/silt and, to a lesser degree, gravel (Lane *et al.* 1996c). Pugnose Shiner generally spawn when the water temperature is between 21 and 29°C, which occurs in June in Ontario waters (Holm and Mandrak 2002). The presence of submergent aquatic vegetation appears to play an important role in the spawning process (Leslie and Timmins 2002). This is supported by an observation made by Becker (1983), where it was noted that the Pugnose Shiner was observed to move to shallower depths once aquatic vegetation appeared, prior to spawning events.

### YOUNG-OF-THE-YEAR (YOY) & JUVENILE

Pugnose Shiner YOY are associated with heavily-vegetated, shallow (2 m maximum depth) habitats (Lane *et al.* 1996b). Leslie and Timmins (2002) noted that larval Pugnose Shiner were associated with stonewort (*Chara vularis*), Eurasian watermilfoil, wild celery (*Vallisneria americana*), pondweeds (*Potamogeton* spp.) and naiad (*Najas flexilis*). Although there are limited data on juvenile Pugnose Shiner habitat requirements, these may be inferred from other life stages because Pugnose Shiner habitat requirements seem to be similar across all known life stages.

### ADULT

Similar to all other life stages, adult Pugnose Shiner are typically found in clear, heavily-vegetated lakes and embayments (Scott and Crossman 1973; Carlson 1997). Although Pugnose Shiner have also been recorded from river systems (i.e., St. Lawrence, Teeswater and Canard rivers), it should be noted that their presence in these systems is restricted to areas with characteristics similar to coastal wetlands and lake systems. Substrates generally associated with the presence of Pugnose Shiner include sand, silt, organic, clay, and marl (Lane *et al.* 1996a). Pugnose Shiner are also generally collected at shallow water depth (less than 2 to 3 metres), although it is thought that they may move into deeper water during the cooler months, making capture difficult (Becker 1983; Lane *et al.* 1996a; Holm and Mandrak 2002). Although it is generally believed that Pugnose Shiner prefer waters with low turbidity (Scott and Crossman 1973; Holm and Mandrak 2002), this species has been captured on occasion in turbid areas (Holm and Mandrak 2002).

Pugnose Shiner are always very closely associated with dense macrophytes (Becker 1983), which may include both emergent, and submergent species. Specifically, Pugnose Shiner are noted to be associated with filamentous algae, submergent macrophytes, such as wild celery, and pondweeds (*Potamogeton* spp.), and emergent macrophytes, such as cattail (*Typha* spp.), bulrush (*Scirpus* spp.), and sedge (*Carex* spp.) (Becker 1983; Holm and Mandrak 2002). Pugnose Shiner is also highly associated with the presence of an introduced macrophyte species, Eurasian watermilfoil; however, it has been noted that the presence of Eurasian watermilfoil may have led to the extirpation of Pugnose Shiner and several other minnow species from a Wisconsin lake (Lyons 1989).

Feeding habits of the Pugnose Shiner have been described as both detritivore (feeding on decomposing organic matter; Goldstein and Simon 1999) and omnivore (feeding on stonewort, filamentous green algae, cladocerans, small leeches and caddisfly larvae; Holm and Mandrak 2002).

## **RESIDENCE**

Residence is defined in SARA as a, "dwelling-place, such as a den, nest or other similar area or place, that is occupied or habitually occupied by one or more individuals during all or part of their life cycles, including breeding, rearing, staging, wintering, feeding or hibernating".

Residence is interpreted by DFO as being constructed by the organism. In the context of the above narrative description of habitat requirements during YOY, juvenile and adult life stages, Pugnose Shiner do not construct residences during their life cycle.

## **THREATS**

A wide variety of threats negatively impact Pugnose Shiner across its range. The greatest threats to the survival and persistence of Pugnose Shiner are related to the degradation and loss of preferred habitat. These threats encompass the physical loss of habitat, including the removal and control of aquatic vegetation and habitat modifications, and habitat degradation through sediment and nutrient loading. Although habitat loss and degradation is thought to be one of the largest threats to Pugnose Shiner, population declines in highly protected areas, such as Point Pelee National Park, suggest that other threats are also having significant effects on the survivorship of Pugnose Shiner. Changes in trophic dynamics may be negatively affecting Pugnose Shiner populations (Holm and Mandrak 2002). The presence of introduced species, including exotic fishes, and aquatic plants may also negatively impact Pugnose Shiner. The degree to which incidental harvest through the baitfish industry affects Pugnose Shiner is currently unknown, but this industry may pose a threat to the persistence of Pugnose Shiner populations. Due to the specific habitat vulnerabilities of the Pugnose Shiner, it is thought that climate change may have both direct and indirect effects on Pugnose Shiner populations, although these effects are difficult to quantify. It is important to note that these threats may not always act independently on Pugnose Shiner populations; rather, one threat may directly affect another, or the interaction between two threats may introduce an interaction effect on the Pugnose Shiner populations. It is quite difficult to quantify these interactions and; therefore, each threat is discussed independently.

## **HABITAT MODIFICATIONS**

Physical loss of Pugnose Shiner habitat can occur through habitat modifications, resulting from urban and shoreline development. Modifications can result in shoreline hardening, wetland drainage and infilling, dock and marina construction, creation of artificial dykes, groynes, and jetties (Holm and Mandrak 2002). Although there is no quantitative information regarding the number of Pugnose Shiner affected by human activities in Canada, loss of habitat, from a combination of shoreline development and the removal of littoral zone macrophytes, was credited for the extirpation of Pugnose Shiner from two Wisconsin lakes (Holm and Mandrak 2002). Leslie and Timmins (2002) hypothesized that the destruction of preferred habitat throughout the Great Lakes has resulted in a loss of connectivity between fragmented populations, and fragmentation may be inhibiting gene flow between populations (Holm and Mandrak 2002). There is currently no quantitative information available on the amount of Pugnose Shiner habitat lost to habitat modifications making it impossible to assess the magnitude by which habitat modifications are limiting Pugnose Shiner recovery.

## **AQUATIC VEGETATION REMOVAL**

A habitat modification that requires specific attention is the loss of aquatic vegetation. Pugnose Shiner is known to use the shallow, heavily-vegetated nearshore area for many of its life processes. Pugnose Shiner are known to use these areas as cover from predators, foraging habitat, as well as spawning and nursery grounds (Holm and Mandrak 2002). Destruction and

removal of aquatic vegetation in the nearshore area of both lakes and streams may have detrimental effects on associated Pugnose Shiner populations. In addition to the implications of vegetation removal, the physical act of removing aquatic vegetation may also have negative impacts on Pugnose Shiner. Mechanical removal of vegetation may result in a disruption of the sediment leading to increased turbidity levels.

### **SEDIMENT LOADING**

Many historical accounts of Pugnose Shiner indicate intolerance of environmental degradation and high sensitivity to increases in turbidity (Scott and Crossman 1973; Trautman 1981; Becker 1983). Stream bank erosion, leading to increases in sediment loads, can be the result of agricultural practices (e.g., livestock river access), bridge crossings, and other construction activities (SRRT 2001). Other processes leading to increased sediment loads include channel shortening and channelization, which alter the natural meandering patterns of the waterway (SRRT 2001). An increase in agricultural land and water use may increase turbidity in certain areas to levels intolerable to the Pugnose Shiner. Negative effects of increased turbidity on Pugnose Shiner may include direct impacts on respiration rates and vision, leading to altered foraging behaviour, or indirect impacts on preferred habitat through decreased water clarity. A decrease in water clarity may impede light penetration, decreasing macrophyte growth, resulting in a loss of preferred habitat for the Pugnose Shiner. Increased turbidity may also affect Pugnose Shiner reproduction through various mechanisms; smothering eggs deposited in the substrate, degrading spawning habitat, or decreasing visibility, which may be necessary for spawning and courtship behaviours.

### **NUTRIENT LOADING**

Degradation of Pugnose Shiner preferred habitat may also result from increases in nutrient (nitrates and phosphorus) loading. Increased nutrient loading can be the result of fertilizer releases into the waterbody, loading from sewage treatment plants, and nutrient runoff from manure piles (SRRT 2001; Page and Retzer 2002). These increased nutrient levels can subsequently lead to the development of algal blooms and, consequently, to decreased levels of dissolved oxygen once the blooms begin to senesce (EERT 2008). Nutrient loading has been listed as a primary threat to Long Point Bay, Point Pelee National Park, and Rondeau Bay, which are all areas historically or currently occupied by Pugnose Shiner (EERT 2008).

### **EXOTIC SPECIES**

The introduction of exotic species, both fishes and aquatic vegetation, to native Pugnose Shiner locations may also have an unfavourable effect on the local Pugnose Shiner population. The feeding behaviour of Common Carp is known to have serious negative impacts on aquatic systems by uprooting aquatic vegetation and increasing turbidity levels (Lougheed *et al.* 1998; Lougheed *et al.* 2004). This feeding behaviour may have significant effects on Pugnose Shiner, which require aquatic vegetation for many of their life processes and are extremely sensitive to turbidity. The effect that other exotic fish species may have on Pugnose Shiner populations is currently unknown. The use of live baitfish, one vector commonly associated with the introduction of exotic fish species, should be limited in areas known to be inhabited by Pugnose Shiner to reduce the risk of introduction.

It is also well known that exotic aquatic macrophytes can drastically alter the aquatic vegetation complex in aquatic systems by outcompeting native plants. One such plant, Eurasian watermilfoil, is known to grow into dense vegetation mats, blocking sunlight to submergent macrophytes, increasing phosphorous and nitrogen inputs, increasing pH and temperature, and decreasing dissolved oxygen, creating an unsuitable environment for Pugnose Shiner and many other fishes (OFAH 2009). Eurasian watermilfoil was associated with the extirpation of eight fish

species, including Pugnose Shiner, in one Wisconsin lake (Lyons 1989). The removal of Eurasian watermilfoil may also be detrimental to Pugnose Shiner, as removal generally involves the application of the herbicide 2,4-D or mechanical harvesting (EERT 2008). Eurasian watermilfoil may be of particular importance to Pugnose Shiner populations of Point Pelee National Park, Rondeau Bay and the St. Clair/Detroit River where it has flourished, although it is not known when the species became established, making it difficult to draw a causal relationship between the presence of Eurasian watermilfoil and the decline of Pugnose Shiner.

#### **BAITFISH INDUSTRY (INCIDENTAL HARVEST)**

The use of Pugnose Shiner as a baitfish is illegal in Ontario (OMNR 2008); however, baitfish harvesting and sale occurs within the range of Pugnose Shiner and it may be caught incidentally. There are two typical baitfish harvest methods used in the baitfish industry. The first consists of a lacustrine nearshore baitfish harvest, which generally targets Emerald Shiner (*Notropis atherinoides*) habitat consisting of clear and sandy-bottom areas. This type of habitat is inconsistent with Pugnose Shiner preferred habitat and, therefore, the threat of incidental harvest from this method is thought to be negligible (A. Drake, University of Toronto, pers. comm.). Of greater concern, is the inland baitfish harvest industry. This type of baitfish harvest generally occurs in rivers and streams at road crossings which provide easy access to the waterway. This type of harvest may occur in areas with habitat similar to Pugnose Shiner preferred habitat but, due to the rarity of this species and sparse distribution, the probability of incidental capture is still considered to be low and may only affect a few populations (A. Drake, University of Toronto, pers. comm.).

#### **CHANGES IN TROPHIC DYNAMIC**

In areas protected from habitat loss and degradation, another factor that may be playing a role in the decline of Pugnose Shiner populations is shifts in trophic dynamics. These shifts include an increase in the abundance and diversity of predator species, and an increase in species that may be competing with Pugnose Shiner for resources (Holm and Boehm 1998; Holm and Mandrak 2002). A shift from a cyprinid-dominated fish assemblage to one that is centrarchid-dominated was noted as one of the leading causes of Pugnose Shiner decline in the Old Ausable Channel (ARRT 2005).

Another trophic dynamic shift that may be negatively affecting Pugnose Shiner populations is an increase in the abundance of competitors. Pugnose Shiner food preferences overlap, in large part, with those of juvenile Black Crappie (*Pomoxis nigromaculatus*), Bluegill (*Lepomis macrochirus*) and adult Brook Silverside (*Labidesthes sicculus*), which were first detected in Point Pelee National Park in the late 1950s (Holm and Mandrak 2002). These species may have outcompeted Pugnose Shiner for food resources, playing a role in the decline (and possible extinction) of Pugnose Shiner from Point Pelee National Park. The presence of these competing species with Pugnose Shiner in the Walpole Island complex (Lake St. Clair) is contrary to this hypothesis (Holm and Mandrak 2002).

#### **CLIMATE CHANGE**

Through discussion on the effects of climate change on Canadian fish populations, impacts such as increases in water and air temperatures, changes (decreases) in water levels, shortening of the duration of ice cover, increases in the frequency of extreme weather events, emergence of diseases, and shifts in predator-prey dynamics have been highlighted, all of which may negatively impact native fishes (Lemmen and Warren 2004). Conversely, Chu *et al.* (2005) predicted a potential spread in the distribution of Pugnose Shiner into more northern watersheds under climate change scenarios. However, this species high vulnerability to specific environmental conditions may limit its distribution. Climate change will have wide-reaching

direct and indirect effects on fish species that depend on wetlands (EERT 2008). Since the effects of climate change on Pugnose Shiner are highly speculative, it is difficult to determine the likelihood and impact of this threat on each Pugnose Shiner populations; therefore, the threat of climate change is not included in the following population-specific Threat Status analysis.

## THREAT STATUS

To assess the Threat Status of Pugnose Shiner populations in Canada, each threat was ranked in terms of the Threat Likelihood and Threat Impact on a population by-population basis (Table 4). The Threat Likelihood was assigned as Known, Likely, Unlikely, or Unknown, and the Threat Impact was assigned as High, Medium, Low, or Unknown (Table 5). The Threat Likelihood and Threat Impact for each population were subsequently combined in the Threat Status Matrix (Table 6) resulting in the final Threat Status for each population (Table 7).

**Table 4.** Definition of terms used to describe Threat Likelihood and Threat Impact.

Term	Definition
<b>Threat Likelihood</b>	
Known (K)	This threat has been recorded to occur at site X.
Likely (L)	There is a >50% chance of this threat occurring at site X.
Unlikely (U)	There is a <50% chance of this threat occurring at site X.
Unknown (UK)	There are no data or prior knowledge of this threat occurring at site X.
<b>Threat Impact</b>	
High (H)	If threat was to occur, it <u>would jeopardize</u> the survival or recovery of this population.
Medium (M)	If threat was to occur, it <u>would likely jeopardize</u> the survival or recovery of this population.
Low (L)	If threat was to occur, it <u>would be unlikely to jeopardize</u> the survival or recovery of this population.
Unknown (UK)	There is no prior knowledge, literature or data to guide the assessment of the impact if it were to occur.

**Table 5.** Threat Likelihood and Threat Impact of each Pugnose Shiner population in Canada. Certainty has been associated with the Threat Likelihood (TLH) and Threat Impact (TI) based on the best available data. The Threat Likelihood was assigned as Known (K), Likely (L), Unlikely (U), or Unknown (UK), and the Threat Impact was assigned as High (H), Medium (M), Low (L), or Unknown (UK). Certainty (C) has been classified and is based on: 1= causative studies; 2=correlative studies; and 3=expert opinion. References (Ref) are provided.

Threats	Lake Erie Drainage																			
	Long Point Bay					Canard River					Point Pelee					Rondeau Bay				
	TLH	C	TI	C	Ref	TLH	C	TI	C	Ref	TLH	C	TI	C	Ref	TLH	C	TI	C	Ref
Habitat modifications	K	3	H	3	g	K	3	H	3	c	U	3	H	3	g	L	3	H	3	c
Aquatic vegetation removal	U	3	H	3	f	U	3	H	3	g	U	3	H	3	g	K	3	H	3	c
Sediment loading	L	3	H	3	c	K	3	H	3	c	U	3	H	3	g	K	3	H	3	c
Nutrient loading	L	3	H	3	c	K	3	H	3	c	U	3	H	3	g	K	3	H	3	c
Exotic species	K	3	M	3	c	K	3	M	3	c	K	3	M	3	i	K	3	M	3	c
Baitfish industry	K	3	L	3	d	U	3	L	3	c,d	U	3	L	3	d	U	3	L	3	d
Changes in trophic dynamics	UK	3	L	3	g	UK	3	L	3	g	U	3	L	3	c,e	U	3	L	3	c

a – ARRT (2005)

c – EERT (2008)

e – Holm and Mandrak (2002)

g – Pugnose Shiner Recovery Potential Assessment Meeting Participants (6 October 2009, Burlington, Ontario)

h – D. Bucholtz, Sandbanks Provincial Park, pers. comm.

j – DFO, unpubl. data

b – Nelson *et al.* (2003)

d – A. Drake, University of Toronto, pers. comm.

f – P. Gagnon, LPCA, pers. comm.

g – Pugnose Shiner Recovery Potential Assessment Meeting Participants (6 October 2009, Burlington, Ontario)

i – Surette (2006)

k – B. McNiven, Quinte Conservation Authority, pers. comm.

**Table 5 (continued).** Threat Likelihood and Threat Impact of each Pugnose Shiner population in Canada. Certainty has been associated with the Threat Likelihood (TLH) and Threat Impact (TI) based on the best available data. The Threat Likelihood was assigned as Known (K), Likely (L), Unlikely (U), or Unknown (UK), and the Threat Impact was assigned as High (H), Medium (M), Low (L), or Unknown (UK). Certainty (C) has been classified and is based on: 1= causative studies; 2=correlative studies; and 3=expert opinion.

Threats	Lake Huron Drainage										Lake St. Clair Drainage									
	Old Ausable Channel					Teeswater River					Lake St. Clair					St. Clair NWA				
	TLH	C	TI	C	Ref	TLH	C	TI	C	Ref	TLH	C	TI	C	Ref	TLH	C	TI	C	Ref
Habitat modifications	K	3	H	3	a,b	UK	3	H	3	g	K	3	H	3	c	K	3	H	3	c
Aquatic vegetation removal	U	3	H	3	g	UK	3	H	3	g	U	3	H	3	c	U	3	H	3	g
Sediment loading	K	3	H	3	a,b	UK	3	H	3	g	K	3	H	3	c	U	3	H	3	g
Nutrient loading	K	3	H	3	a,b	UK	3	H	3	g	K	3	H	3	c	U	3	H	3	g
Exotic species	K	3	M	3	a,b	UK	3	M	3	g	K	3	M	3	c	K	2	M	3	j
Baitfish industry	U	3	L	3	d	L	3	L	3	d	K	3	L	3	d	U	3	L	3	d
Changes in trophic dynamics	K	3	L	3	e	UK	3	L	3	g	UK	3	L	3	g	UK	3	L	3	g

a – ARRT (2005)

c – EERT (2008)

e – Holm and Mandrak (2002)

g – Pugnose Shiner Recovery Potential Assessment Meeting Participants (6 October 2009, Burlington, Ontario)

h – D. Bucholtz, Sandbanks Provincial Park, pers. comm.

j – DFO, unpubl. data

b – Nelson *et al.* (2003)

d – A. Drake, University of Toronto, pers. comm.

f – P. Gagnon, LPCA, pers. comm.

i – Surette (2006)

k – B. McNiven, Quinte Conservation Authority, pers. comm.

**Table 5 (continued).** Threat Likelihood and Threat Impact of each Pugnose Shiner population in Canada. Certainty has been associated with the Threat Likelihood (TLH) and Threat Impact (TI) based on the best available data. The Threat Likelihood was assigned as Known (K), Likely (L), Unlikely (U), or Unknown (UK), and the Threat Impact was assigned as High (H), Medium (M), Low (L), or Unknown (UK). Certainty (C) has been classified and is based on: 1= causative studies; 2=correlative studies; and 3=expert opinion. References (Ref) are provided.

Threats	Lake Ontario Drainage														
	St. Lawrence River					Gananoque River					West Lake				
	TLH	C	TI	C	Ref	TLH	C	TI	C	Ref	TLH	C	TI	C	Ref
Habitat modifications	U	3	H	3	g	UK	3	H	3	g	U	3	H	3	h,k
Aquatic vegetation removal	U	3	H	3	g	UK	3	H	3	g	U	3	H	3	h,k
Sediment loading	L	3	H	3	g	UK	3	H	3	g	L	3	H	3	h,k
Nutrient loading	L	3	H	3	g	UK	3	H	3	g	L	3	H	3	h,k
Exotic species	L	3	M	3	g	UK	3	M	3	g	K	3	M	3	h,k
Baitfish industry	L	3	L	3	d	U	3	L	3	d	U	3	L	3	d
Changes in trophic dynamics	UK	3	L	3	g	UK	3	L	3	g	UK	3	L	3	h,k

a – ARRT (2005)

c – EERT (2008)

e – Holm and Mandrak (2002)

g – Pugnose Shiner Recovery Potential Assessment Meeting Participants (6 October 2009, Burlington, Ontario)

h – D. Bucholtz, Sandbanks Provincial Park, pers. comm.

j – DFO, unpubl. data

b – Nelson *et al.* (2003)

d – A. Drake, University of Toronto, pers. comm.

f – P. Gagnon, LPCA, pers. comm.

i – Surette (2006)

k – B. McNiven, Quinte Conservation Authority, pers. comm.

**Table 6.** The Threat Status Matrix combines the Threat Likelihood and Threat Impact rankings to establish the Threat Status for each Pugnose Shiner population in Canada. The resulting Threat Status has been categorized as Poor, Fair, Good, or Unknown.

		Threat Impact			
		Low (L)	Medium (M)	High (H)	Unknown (UK)
Threat Likelihood	Known (K)	Low	Medium	High	Unknown
	Likely (L)	Low	Medium	High	Unknown
	Unlikely (U)	Low	Low	Medium	Unknown
	Unknown (UK)	Unknown	Unknown	Unknown	Unknown

The Threat Status results were used to assess the overall effect each threat may have on Canadian Pugnose Shiner populations as a whole. Each threat was categorized in terms of both Spatial and Temporal Extent (Table 8). Spatial Extent was categorized as Widespread [threat is likely to affect a majority of Ontario Pugnose Shiner populations (i.e., threat affecting five or more populations)] or Local [threat is likely to not affect the majority of Ontario Pugnose Shiner populations (i.e., threat affecting less than five populations)]. Temporal Extent was categorized as Chronic (threat that is likely to have a long-lasting, or re-occurring effect on a population) or Ephemeral (threat that is likely to have a short-lived, or non-recurring effect on a population).

**Table 7.** Threat Status for all Pugnose Shiner populations in Canada, resulting from an analysis of both the Threat Likelihood and Threat Impact. The number in brackets refers to the level of certainty assigned to each Threat Status, which is reflective of the lowest level of certainty associated with either initial parameter (Threat Likelihood, or Threat Impact). Clear cells do not necessarily represent a lack of a relationship between a population and a threat; rather, they indicate that either the Threat Likelihood or Threat Impact was Unknown.

	Lake Erie drainage				Lake Huron drainage		Lake St. Clair drainage		Lake Ontario drainage		
Threats	Long Point Bay	Canard River	Point Pelee	Rondeau Bay	Old Ausable Channel	Teeswater River	Lake St. Clair	St. Clair NWA	St. Lawrence River	Gananoque River	West Lake
Habitat modifications	High (3)	High (3)	Medium (3)	High (3)	High (3)	Unknown (3)	High (3)	High (3)	Medium (3)	Unknown (3)	Medium (3)
Aquatic vegetation removal	Medium (3)	Medium (3)	Medium (3)	High (3)	Medium (3)	Unknown (3)	Medium (3)	Medium (3)	Medium (3)	Unknown (3)	Medium (3)
Sediment loading	High (3)	High (3)	Medium (3)	High (3)	High (3)	Unknown (3)	High (3)	Medium (3)	High (3)	Unknown (3)	High (3)
Nutrient loading	High (3)	High (3)	Medium (3)	High (3)	High (3)	Unknown (3)	High (3)	Medium (3)	High (3)	Unknown (3)	High (3)
Exotic species	Medium (3)	Medium (3)	Medium (3)	Medium (3)	Medium (3)	Unknown (3)	Medium (3)	Medium (3)	Medium (3)	Unknown (3)	Medium (3)
Baitfish industry	Low (3)	Low (3)	Low (3)	Low (3)	Low (3)	Low (3)	Low (3)	Low (3)	Low (3)	Low (3)	Low (3)
Changes in trophic dynamics	Unknown (3)	Unknown (3)	Low (3)	Low (3)	Low (3)	Unknown (3)	Unknown (3)	Unknown (3)	Unknown (3)	Unknown (3)	Unknown (3)

**Table 8.** Overall effect of threats on Canadian Pugnose Shiner populations.

Threat	Spatial Extent	Temporal Extent
Habitat modifications	Widespread	Chronic
Aquatic vegetation removal	Widespread	Chronic
Sediment loading	Widespread	Chronic
Nutrient loading	Widespread	Chronic
Exotic species	Widespread	Chronic
Baitfish industry	Widespread	Ephemeral
Changes in trophic dynamics	Local	Chronic

## MITIGATIONS AND ALTERNATIVES

Numerous threats affecting Pugnose Shiner populations are related to habitat loss or degradation. Habitat-related threats to Pugnose Shiner have been linked to the Pathways of Effects developed by DFO Fish Habitat Management (FHM) (Table 9). DFO FHM has developed guidance on generic mitigation measures for 19 Pathways of Effects for the protection of aquatic species at risk in the Ontario Great Lakes Area (Coker *et al.* 2010). This guidance should be referred to when considering mitigation and alternative strategies. Additional mitigation and alternative measures, specific to exotic species and incidental harvest through the baitfish industry are listed below.

**Table 9.** Threats to Pugnose Shiner populations and the Pathways of Effect associated with each threat. See Appendix I for a key to the Pathways.

Threats	Pathway(s)
Habitat modifications	1, 2, 3, 4, 5, 7, 8, 10, 11, 13, 14, 15, 16, 18
Aquatic vegetation removal	10, 11, 15
Sediment loading	1, 2, 3, 4, 5, 6, 7, 8, 10, 11, 12, 13, 15, 16, 18
Nutrient loading	1, 4, 7, 8, 11, 12, 13, 14, 15, 16
Exotic species	
Baitfish industry	
Changes in trophic dynamics	

## EXOTIC SPECIES

As discussed in the **THREATS** section, Common Carp and Eurasian watermilfoil introduction and establishment could have negative effects on Pugnose Shiner populations.

### Alternatives

- Unauthorized
  - None.
- Authorized
  - Use only native species.
  - Follow the National Code on Introductions and Transfers of Aquatic Organisms for all aquatic organism introductions (DFO 2003).

### **Mitigation**

- Physically remove non-native species from areas known to be inhabited by Pugnose Shiner.
- Monitor watersheds for exotic species that may negatively affect Pugnose Shiner populations directly, or negatively affect preferred habitat of the Pugnose Shiner.
- Develop a plan to address potential risks, impacts, and proposed actions if monitoring detects the arrival or establishment of an exotic species.
- Prohibit the use of live baitfish in areas known to be inhabited by Pugnose Shiner.
- Introduce a public awareness campaign.

### **BAITFISH INDUSTRY (INCIDENTAL HARVEST)**

As discussed in the **THREATS** section, incidental harvest of Pugnose Shiner through the baitfish industry was recognized as a potentially low risk threat.

### **Alternatives**

- Prohibit the harvest of baitfish in areas where Pugnose Shiner are known to exist.

### **Mitigation**

- Provide information and education to bait harvesters on Pugnose Shiner, and request the voluntary avoidance of occupied Pugnose Shiner areas.
- Immediate release of all blackline shiners (Pugnose Shiner, Blacknose Shiner, Blackchin Shiner, and Bridle Shiner) if incidentally caught. The release of all blackline shiners is necessary due to difficulties in properly identifying this group of fishes.

## **SOURCES OF UNCERTAINTY**

There are many sources of uncertainty surrounding the biology and ecology of Pugnose Shiner. Its small size, elusive nature and preference for areas with dense macrophyte coverage makes Pugnose Shiner difficult to sample and, therefore, populations may be under-represented by the few individuals caught. Information regarding population size and the number of mature individuals, as well as recruitment and mortality rates, is not available for this species. The life history of this species is also poorly understood.

Another larger source of uncertainty is related to the Pugnose Shiner distribution and population estimates and population structure. Limited records, represented by a few individuals, have been noted for Canard River, St. Clair National Wildlife Area, Teeswater River, and West Lake. Repeated standardized sampling in these locations is necessary to determine if reproducing populations are present. In addition, standardized sampling is needed at all locations where Pugnose Shiner is known to exist to determine population size, distribution, stability, and number of reproducing individuals. Repeated standardized sampling in all areas is also necessary to determine Pugnose Shiner abundance over time to determine the trajectory of these populations. Repeated standardized sampling would result in increased certainty when assigning Population Status to Pugnose Shiner populations. Furthermore, baseline data required to monitor Pugnose Shiner population trends could also be used to measure the success of any recovery measures. There is also a need to assess genetic variation across all Canadian Pugnose Shiner populations to determine population structure.

The current distribution and extent of suitable Pugnose Shiner habitat should be investigated and mapped. These areas should be the focus of future targeted sampling efforts for this species. There is also a need to identify habitat requirements for each life stage. There is very little information available for both YOY and juvenile Pugnose Shiner habitat requirements, necessitating the inference of these requirements from the adult life stage. Novel sampling techniques should be applied to investigate whether or not Pugnose Shiner are utilizing deeper habitats.

A thorough understanding of the threats affecting the decline of Pugnose Shiner populations is also lacking. Numerous threats have been identified for Canadian Pugnose Shiner populations, although the severity of these threats is currently unknown. There is a need for more causative studies to evaluate the impact of each threat on each Pugnose Shiner population with greater certainty. A greater knowledge of the effects of habitat modifications and aquatic vegetation removal on Pugnose Shiner populations and spawning areas is required. The Pugnose Shiner is considered to be a turbidity-intolerant species, although there is a lack of evidence on the direct or indirect effects of siltation on Pugnose Shiner populations. Incidental harvest through the baitfish industry as well as shifts in trophic dynamics may also play a role in the decline of Pugnose Shiner, although the degree to which these threats are affecting Pugnose Shiner populations is still unknown.

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## **Appendix I. Key to Pathways of Effect.**

1. Vegetation clearing
2. Grading
3. Excavation
4. Use of explosives
5. Use of industrial equipment
6. Cleaning or maintenance of bridges or other structures
7. Riparian planting
8. Streamside livestock grazing
9. Marine seismic surveys
10. Placement of material or structures in water
11. Dredging
12. Water extraction
13. Organic debris management
14. Wastewater management
15. Addition or removal of aquatic vegetation
16. Change in timing, duration and frequency of flow
17. Fish passage issues
18. Structure removal
19. Placement of marine finfish aquaculture site

